CLAIMS

1. A polarization conversion element comprising an optical waveguide formed on a substrate,

the optical waveguide comprising sequentially a first waveguide portion, a polarization rotation portion, and a second waveguide portion, wherein:

in the first waveguide portion, an eigen mode of waveguide light on a sectional surface of the first waveguide portion comprises at least one TE mode and one TM mode, and an effective refractive index of the TE mode having the highest effective refractive index is higher than an effective refractive index of the TM mode;

in the second waveguide portion, an eigen mode of waveguide light on a sectional surface of the second waveguide portion comprises at least one TE mode and one TM mode, and an effective refractive index of the TM mode is higher than an effective refractive index of the TE mode having the highest effective refractive index;

a height of a waveguide structure of the first waveguide portion and a height of a waveguide structure of the second waveguide portion are equal to each other;

a waveguide structure of the polarization rotation portion has at least two heights in a height direction from the substrate, and the waveguide structure comprises a thick plate portion having the same height as that of the waveguide structure of the first waveguide portion and the second waveguide portion, and a thin plate portion having a thickness thinner than that of the thick plate portion;

the waveguide structure of the polarization rotation portion comprises a portion of which a sectional surface is asymmetric in a width direction and is also asymmetric in a height direction; and

waveguide structures having the same height continuously exist between the

waveguide structure of the first waveguide portion, the thick plate portion of the polarization rotation portion, and the waveguide structure of the second waveguide portion.

2. The polarization conversion element according to Claim 1,

wherein a width of the waveguide structure is continuously changed without comprising a discontinuous point between the first waveguide portion, the polarization rotation portion, and the second waveguide portion, along a waveguide direction.

3. The polarization conversion element according to Claim 1 or 2,

wherein the sectional surface of the waveguide structure of the first waveguide portion is in the shape of a rectangle in which the width direction is larger than the height direction.

4. The polarization conversion element according to Claim 1 or 2,

wherein the waveguide structure of the first waveguide portion is a rib type structure including a thick rib portion and a thin slab portion.

5. The polarization conversion element according to Claim 4,

wherein a height of the thick plate portion of the polarization rotation portion is equal to a height of the rib portion, and a height of the thin plate portion is equal to a height of the slab portion.

6. The polarization conversion element according to any one of Claims 1 to 5,

wherein the sectional surface of the waveguide structure of the second waveguide

portion is in the shape of a rectangle in which the width direction is smaller than the height direction.

7. The polarization conversion element according to any one of Claims 1 to 6, wherein the waveguide structure of the second waveguide portion continuously comprises a portion of which a sectional surface linearly extending with a constant width is in the shape of a rectangle in the thick plate portion.

8. The polarization conversion element according to any one of Claims 1 to 5, wherein the waveguide structure of the second waveguide portion is a rib type structure comprising a thick rib portion and a thin slab portion.

9. The polarization conversion element according to any one of Claims 1 to 8, wherein the eigen mode of the waveguide light on the sectional surface of the first waveguide portion comprises one TE mode and one TM mode, or comprises at least two TE modes and one TM mode having an effective refractive index higher than that of the TE mode having the second highest effective refractive index.

10. The polarization conversion element according to any one of Claims 1 to 9, wherein the second waveguide portion is connected to a mode expansion portion in which a width of a waveguide structure expands along a direction away from the polarization rotation portion.

11. The polarization conversion element according to any one of Claims 1 to 9, wherein any one or both of the first waveguide portion and the second waveguide

portion is connected to a tapered mode conversion unit in which a width of a waveguide structure becomes narrower along a direction away from the polarization rotation portion.

12. The polarization conversion element according to any one of Claims 1 to 11, wherein a lower surface of the thick plate portion and a lower surface of the thin plate portion of the polarization rotation portion have the same height from the substrate.

13. The polarization conversion element according to any one of Claims 1 to 11, wherein an upper surface of the thick plate portion and an upper surface of the thin plate portion of the polarization rotation portion have the same height from the substrate.

14. The polarization conversion element according to any one of Claims 1 to 13, wherein the waveguide structure is a core.

15. The polarization conversion element according to any one of Claims 1 to 13, wherein the waveguide structure is formed of a core and an upper cladding which is laminated on the core and has a width of less than or equal to a width of the core.

16. A DP-QPSK modulator comprising the polarization conversion element according to any one of Claims 1 to 15.

CLAIMS

1. A polarization conversion element comprising an optical waveguide formed on a substrate,

the optical waveguide comprising sequentially a first waveguide portion, a polarization rotation portion, and a second waveguide portion, wherein:

in the first waveguide portion, an eigen mode of waveguide light on a sectional surface of the first waveguide portion comprises at least one TE mode and one TM mode, and an effective refractive index of the TE mode having the highest effective refractive index is higher than an effective refractive index of the TM mode having the highest effective refractive index;

in the second waveguide portion, an eigen mode of waveguide light on a sectional surface of the second waveguide portion comprises at least one TE mode and one TM mode, and an effective refractive index of the TM mode having the highest effective refractive index is higher than an effective refractive index of the TE mode having the highest effective refractive index;

a height of a waveguide structure of the first waveguide portion and a height of a waveguide structure of the second waveguide portion are equal to each other;

a waveguide structure of the polarization rotation portion has at least two heights in a height direction from the substrate, and the waveguide structure comprises a thick plate portion having the same height as that of the waveguide structure of the first waveguide portion and the second waveguide portion, and a thin plate portion having a thickness thinner than that of the thick plate portion;

the waveguide structure of the polarization rotation portion comprises a portion of which a sectional surface is asymmetric in a width direction and is also asymmetric in a

height direction;

waveguide structures having the same height continuously exist between the waveguide structure of the first waveguide portion, the thick plate portion of the polarization rotation portion, and the waveguide structure of the second waveguide portion; and

the polarization rotation portion has a length of the longitudinal direction that allows an mode conversion to be performed adiabatically.

2. The polarization conversion element according to Claim 1, wherein a width of the thin plate portion of the polarization rotation portion is continuously changed toward the second waveguide portion.

3. The polarization conversion element according to Claim 1 or 2,

wherein a width of the waveguide structure is continuously changed without comprising a discontinuous point between the first waveguide portion, the polarization rotation portion, and the second waveguide portion, along a waveguide direction.

4. The polarization conversion element according to any one of Claims 1 to 3,

wherein the sectional surface of the waveguide structure of the first waveguide portion is in the shape of a rectangle in which the width direction is larger than the height direction.

5. The polarization conversion element according to any one of Claims 1 to 3,

wherein the waveguide structure of the first waveguide portion is a rib type structure including a thick rib portion and a thin slab portion.

6. The polarization conversion element according to Claim 5,

wherein a height of the thick plate portion of the polarization rotation portion is equal to a height of the rib portion, and a height of the thin plate portion is equal to a height of the slab portion.

7. The polarization conversion element according to any one of Claims 1 to 6,

wherein the sectional surface of the waveguide structure of the second waveguide portion is in the shape of a rectangle in which the width direction is smaller than the height direction.

8. The polarization conversion element according to any one of Claims 1 to 7,

wherein the waveguide structure of the second waveguide portion continuously comprises a portion of which a sectional surface linearly extending with a constant width is in the shape of a rectangle in the thick plate portion.

9. The polarization conversion element according to any one of Claims 1 to 6,

wherein the waveguide structure of the second waveguide portion is a rib type structure comprising a thick rib portion and a thin slab portion.

10. The polarization conversion element according to any one of Claims 1 to 9,

wherein the eigen mode of the waveguide light on the sectional surface of the first waveguide portion comprises one TE mode and one TM mode, or comprises at least two TE modes and one TM mode having an effective refractive index higher than that of the TE mode having the second highest effective refractive index.

11. The polarization conversion element according to any one of Claims 1 to 10, wherein the second waveguide portion is connected to a mode expansion portion in which a width of a waveguide structure expands along a direction away from the polarization rotation portion.

12. The polarization conversion element according to any one of Claims 1 to 10, wherein any one or both of the first waveguide portion and the second waveguide portion is connected to a tapered mode conversion unit in which a width of a waveguide structure becomes narrower along a direction away from the polarization rotation portion.

13. The polarization conversion element according to any one of Claims 1 to 12, wherein a lower surface of the thick plate portion and a lower surface of the thin plate portion of the polarization rotation portion have the same height from the substrate.

14. The polarization conversion element according to any one of Claims 1 to 12, wherein an upper surface of the thick plate portion and an upper surface of the thin plate portion of the polarization rotation portion have the same height from the substrate.

15. The polarization conversion element according to any one of Claims 1 to 14, wherein the waveguide structure is a core.

16. The polarization conversion element according to any one of Claims 1 to 14, wherein the waveguide structure is formed of a core and an upper cladding which is laminated on the core and has a width of less than or equal to a width of the core.

17. A DP-QPSK modulator comprising the polarization conversion element according to any one of Claims 1 to 16.